Calculation of Selenium Targets for New River West Habitat

Draft for Charrette Discussion, 11/9/2017

Using data collected and compiled in Sickman et al., 2011, we can estimate the concentration in fish tissue, invertebrates, and bird eggs, given a concentration in the water column. The relationships are primarily in the form of linear ratios, or trophic transfer factors (TTFs), that represent bioaccumulation from one trophic level to the next (Presser and Luoma, 2011). Thus, a TTF of 100 means that the predator organism has a tissue concentration 100 times greater than the prey concentration. The TTF concept is shown schematically in Figure 1 (reproduced from Sickman et al. 2011). The TTF approach has been used to relate water column and tissue targets in regulatory efforts in California (i.e., the Newport Bay selenium total maximum daily load or TMDL, and the San Francisco Bay selenium TMDL).

The TTF values are typically derived from co-located measurements that have been reported in different pilot projects, specifically the saline habitat project (SHP), the New River Pilot wetlands, and drains in the vicinity of the Salton Sea. Sickman et al. 2011, prepared for DWR as part of the Species Conservation Habitat EIR/EIS, provides a comprehensive review of the data available at the time the document was prepared. The document calculated partitioning between water and sediment, and TTFs in different trophic levels (invertebtrates, fish tissue, and bird eggs). Since that time, additional water quality data have been collected, but limited tissue and sediment concentration data have been reported. Thus, the Sickman et al. 2011 report is still valid as a basis for developing water quality targets.

We have used the most recent full year's worth of water quality data (calendar year 2016 data reported by the Bureau of Reclamation), and partitioning coefficients and TTFs reported by Sickman et al. 2011 to compute bird egg and fish tissue concentrations. These calculations assume a mixing ratio between Salton Sea water and New River water that is based on flow targets presented by Ruey-Wen Wang (September, 2017): the mix of waters is targeted to achieve a desired salinity in a mixing pond. Sickman et al. provides a mean, median, and 75th percentile value of the partitioning coefficients and TTFs from the source studies. To be conservative, we use the 75th percentile value in the calculations.

Roberts, Carol A 11/22/2017 1:23 PM
Comment [1]: Could you provide more details as to how representative these values are for use in long-term planning?

The 75:25 mixing ratio between New River and Salton Sea water (Table 1 and attached Excel file) results in bird egg concentrations that range from 4.9 mg/kg to 8.3 mg/kg. For invertebrate feeding birds, and the 75th percentile values of partitioning coefficients and TTFs, the expected concentrations are slightly higher than a generic bird egg toxicity threshold of 8 mg/kg dry weight (Hamilton, 2004).

Roberts, Carol A 11/22/2017 12:45 PM
Comment [2]: Please see the revised table below.

Fish tissue concentrations are estimated to be 5.8 mg/kg, lower that USEPA's 2016 proposed whole body fish tissue criterion of 8.5 mg/kg (https://www.epa.gov/wqc/aquatic-life-criterion-selenium-documents). Water quality values estimated for the ponds exceed the USEPA water quality criterion of 1.5 ug/l for non-flowing waters (lentic systems, 30-day average).

Roberts, Carol A 11/22/2017 12:46 PM
Comment [3]: Please see the revised table below.

Notes/assumptions:

All tissue concentrations for selenium are expressed in terms of dry weight.

If the above calculations were performed with mean partitioning coefficients and TTFs, the bird egg values are lower than the 8 mg/kg toxicity threshold, 2.6 to 4 mg/kg (see Table 1).

Concentrations in the habitat ponds assume mixing but no settling of selenium. This is a conservative assumption.

Concentrations in shallow wetland habitat, created using these ponds, may be higher on account of evaporation.

Roberts, Carol A 11/22/2017 12:47 PM
Comment [4]: Please see the additional comments below.

References:

Hamilton, S.J., 2004. Review of selenium toxicity in the aquatic food chain. Science of the Total Environment, 326(1), pp.1-31.

Presser, T.S. and Luoma, S.N., 2010. A methodology for ecosystem-scale modeling of selenium. Integrated Environmental Assessment and Management, 6(4), pp.685-710.

Sickman, J., J. Tobin, D. Schlenk, C. Amrhein, W. Walton, D. Bennett, and M. Anderson. 2011. Proposed modeling of Se bioaccumulation potential in proposed Species Conservation Habitats of the Salton Sea. Report to the Department of Water Resources.

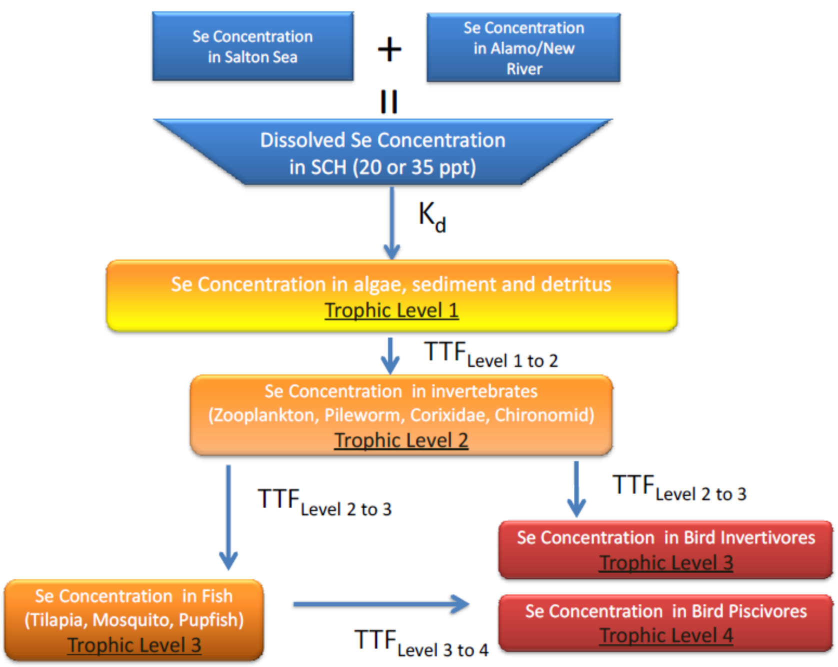

Figure 1. Conceptual model of Se uptake through the food web (Source: Sickman et al. 2011).

Table 1. Selenium Targets for New River West Habitat			
Concentration	**75th percentile bioaccumulation factors**	**Median bioaccumulation factors**	**Source**
New River, Se ug/l	2.41	2.41	BoR Sampling 2016 average
Salton Sea, ug/l	1.51	1.51	BoR Sampling 2016, SS3 surface station
New River Water Fraction, %	75	75	Wang, 2017
Salton Sea Fraction	25	25	Wang, 2017
Pond Se Concentration, ug/l	2.19	2.19	Calculated using mixing ratio
Sediment, Kd	877	588	Sickman et al. 2011, Table 3
Sediment Concentration, mg/kg	1.92	1.28	Calculated using Kd
Invertebrate TTF	3.76	2.75	Sickman et al. 2011, Table 4
Fish (TL3) TTF	3.03	2.4	Sickman et al. 2011, Table 5
Fish Tissue (TL3), mg/Kg DW	5.81	3.08	Calculated using sediment concentration and TTF
Invertebrate tissue, mg/kg DW	7.21	3.53	Calculated using sediment concentration and TTF
Bird Egg, Invertebrate Feeder, TTF	1.15	1.15	Mean, Sickman et al. 2011, Table 7, insufficient data for 75th percentile
Bird Egg, Fish Feeder, TTF	0.85	0.85	Mean, Sickman et al. 2011, Table 8
Bird Egg, Invertebrate Feeder, mg/kg, DW	8.29	4.06	Calculated using invertebrate concentration and TTF
Bird Egg, Fish Feeder, mg/kg DW	4.94	2.62	Calculated using fish concentration and TTF

Please see the revised Table below based on the sources described in the comments (some rounding errors were also corrected).

Roberts, Carol A 11/22/2017 1:12 PM
Comment [5]: It does not seem appropriate to combine the mosquitofish/molly results with the tilapia. There certainly appears to be a difference in risk, and we would expect the proportion of each species in the diet (particularly given the considerably larger size reached by tilapia) to vary across bird species. This warrants greater attention, particularly if we expect tilapia to make up the bulk of the diet for some species (pelicans and cormorants for example). This may be what is provided in Table 5, but it is not how Sickman et al. 2011 did their progressive modeling. They use two TTFs in their calculation: 2.75 for 1 to 2 and 1.31 for 2 to 3, producing a combined factor of 3.60 (see Tables 4, 5, 8 and 9 in the Appendix). If you incorporate t ... [1]

Roberts, Carol A 11/22/2017 11:01 AM
Comment [6]: Recalculated as described above, these concentrations increase to 9.46 and 4.65, respectively.

Roberts, Carol A 11/27/2017 11:26 AM
Comment [7]: Sickman et al. (2011) did not use this factor in their progressive model. It is based on the rather loose relationship between coots and corixids. This should be recalculated using 1.8 as the median TTF (see Tables 2, 3, 6 and 7 in the Appendix). The 75th percentile TTF increases to 2.28. Please see the revised table below.

Roberts, Carol A 11/27/2017 11:26 AM
Comment [8]: We are very uncomfortable using a factor derived from coots and mosquitofish (a questionable relationship to begin with) to model the trophic transfer from tilapia to cormorants, for example. It should be noted that Sickman et al. (2011) did not use this factor in their progressive mod ... [2]

Roberts, Carol A 11/22/2017 10:45 AM
Comment [9]: If you use the factors used by Sickman et al. (2011) in their model calculations (provided in the Appendix), these concentrations become 16.5 at the 75th percentile and 6.39 at the median. This leaves one with a rather different conclusion regarding the appropriateness of this mixing regime.

Roberts, Carol A 11/22/2017 1:14 PM
Comment [10]: If you use the factors used by Sickman et al. (2011) in their actual calculations (provided in the Appendix), these concentrations become 14.2 at the 75th percentile and 6.98 at the median. This leaves one with a very different conclusion regarding the appropriateness of this mixing regime. The difference becomes more striking if yo ... [3]

Table 1. Selenium Targets for New River West Habitat			
Concentration	**75th percentile bioaccumulation factors**	**Median bioaccumulation factors**	**Source**
New River, Se ug/l	2.41	2.41	BoR Sampling 2016 average
Salton Sea, Se ug/l	1.51	1.51	BoR Sampling 2016, SS3 surface station
New River Water Fraction, percent	75	75	Wang, 2017
Salton Sea Fraction, percent	25	25	Wang, 2017
Pond Se Concentration, ug/l	2.19	2.19	Calculated using source concentrations and mixing ratio
Sediment, Kd	877	588	Sickman et al. 2011, Table 3
Sediment Concentration (TL1), mg/kg	1.92	1.29	Calculated using Pond water concentration and Kd
Invertebrate TTF (TL1 → TL2)	3.76	2.75	Sickman et al. 2011, Table 4
Invertebrate tissue (TL2), mg/kg DW	7.22	3.55	Calculated using sediment concentration and Invertebrate TTF
Bird Egg, Invertebrate Feeder, TTF (TL2 → TL3)	2.28	1.80	Sickman et al. 2011, Table 6
Bird Egg, Invertebrate Feeder (TL3), mg/kg, DW	16.5	6.39	Calculated using invertebrate concentration and Bird egg TTF for Invertebrate Feeders
Fish TTF (TL2 → TL3)	1.31	1.31	Mean, Sickman et al. 2011, Table 6
Tilapia TTF (TL1 → TL3)	5.58	4.82	Sickman et al. (2011) Table 5 values for Tilapia
Fish Tissue (TL3), mg/Kg DW	9.46	4.65	Calculated using invertebrate concentration and Fish TTF
Tilapia Tissue (TL3), mg/Kg DW	10.7	6.22	Calculated using sediment concentration and Tilapia TTF
Bird Egg, Fish Feeder, TTF (TL3 → TL4)	1.5	1.5	Sickman et al. 2011, Appendix Tables 4, 5, 8 and 9 (no 75th percentile available)
Bird Egg, Fish Feeder (TL4), mg/kg DW	14.2	6.98	Calculated using fish concentration and Bird egg TTF for Fish Feeders
Bird Egg, Fish Feeder (TL4) relying on Tilapia, mg/kg DW	16.0	9.33	Calculated using Tilapia concentration and TTF for Fish Feeders

Additional Comments provided by the Science Committee:

The models used to predict the behavior of selenium in the aquatic systems treat the marshes as a closed system. They assume that the input is a given selenium concentration, and they calculate the distribution of selenium in the various trophic levels from that starting point. The situation in the field is quite different. We expect concentrations of the inputs to change over time with the implementation of different farming practices and crop types. That was not addressed in the model (other than the ceiling at 10 ug/L which results in unacceptably high concentrations). It is hard to know precisely how different it will be since we are not provided with information about how the marshes will be managed.

In this region of California, the evaporation rate for aquatic surfaces is about 6 acre-feet per acre per year. In a marsh one foot deep, half of the water would evaporate in one month. In the absence of replacement water and biological uptake of selenium, this would double the water-borne selenium concentration. Since selenium-free water is not available, restoring the volume of the marsh with more water from the same sources will double the selenium loading of the marsh. These processes of evaporation and replacement are not addressed in the models used.

This document does not specify how the marshes will be managed. If the marshes are fully drained at regular intervals, for example every two to three months, they will not be able to maintain populations of fish and invertebrates. If, on the other hand, turnover is achieved by water flow-through (that is either constant or includes periodic partial drainage and replacement), much of the selenium that enters the system will bioaccumulate rather than passing through. This is a well-understood effect in marshes, and it is the process used in treatment marshes to reduce the selenium concentration of water exiting the marsh. It occurred in the treatment marshes on the New River (Johnson et al., 2009). This too is not addressed in the models.

The calculations do not provide any assessment of the severity of the impacts anticipated with these concentrations; however, considering the thresholds identified in Appendix I of the Salton Sea SCH Draft EIS/EIR, the concentrations we have provided in our table raise concerns for hatching failure in highly and moderately sensitive species, and teratogenic effects in highly sensitive species that may use the ponds. Given these results, we question the appropriateness of the proposed 75:25 mix of New River and Salton Sea water when the expressed purpose of the ponds is to create wildlife habitat. Also, this analysis does not address the fact that selenium concentrations in the New River and Salton Sea are not anticipated to be static over time. Modeling that includes changes in the concentrations over time would provide a much more complete picture of the long-term viability of these created habitats and allow for design features that can accommodate different mixing regimes. Modeling should also address changes within the ponds that can be anticipated to result from management practices. This will facilitate future adaptive management changes to their operation. We encourage the use of the Red Hill Bay project to maximize information gathering in this regard. While the ability to make adaptive management changes will be limited there, thorough evaluation through sampling, monitoring and additional modeling would be very helpful in incorporating greater management flexibility into future created habitats.